Tio2 Reinforced Al2o3 Composites

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Abstract

In this study, the effect of TiO2 addition on properties of alumina ceramics was investigated. The prepared commercial Alcoa alumina reinforced 0-15 % TiO2 were ground in ball mill for 2 h by wet milling and then powders were shaped dry pressing. After shaping operations, the

samples were sintered 1500-1650 °C for 2 h. Firing shrinkage, relative density, flexural strength and hardness tests were performed and also for characterization x-ray diffraction (XRD) analysis and scanning electron microscopy (SEM) were utilized. It was seen that the TiO2 addition to alumina has effected on properties of alumina, significantly.

Keywords: Alumina, TiO2, Ceramic Composites.

1. INTRODUCTION

Alumina is a consider material for refractory application which has high melting point as 2000 ±30 °C. Also this material was resisted to acids, bases and many liquid metals and glass. Moreover its heat and electrical conducting was very low. Due to have this insulating properties, alumina firstly use in automotive industry as sparking plug. Today alumina is using as cutting tools for machining operation and as a resistant material to corrosion in the chemical industry and as a high temperature materials for heating systems. Furthermore another usage of alumina is special purpose in optic and medical technique application (Ilgar 2008, Rao 2000). Alumina is a ceramic oxide material. Although there are various modifications of Alumina, α–Al2O3 has commercial use (Toy 1994).

As a thin film of TiO2 have many application areas because of superior properties of electrical, chemical and optical. Due to Titanium dioxide has very high melting point, it has many optical applications and optic circuit as coating material. Moreover, titanium dioxide can be used as bio-material and implant due to have high corrosion resistance and biocompatibility (Bardakci 2007).

At the present study, the effect of TiO2 addition on properties of alumina was investigated Mixtures of alumina-TiO2 were shaped by dry pressing and were sintered at 1500-1650 °C temperatures. After sintering, some physical tests were applied to TiO2 reinforced alumina ceramics and characterized by XRD and SEM.

2. EXPERIMENTAL PROCEDURE

In this study, the raw materials were alumina powder (0.4 μm) produced by the Aluminum Company of America (Alcoa A16-SG, USA) and high purity TiO2 (0.1 μm) ceramic powders. TiO2 was added to commercial Alcoa alumina powder in different proportions (0, 5, 10, 15, in wt %). The ratios of alumina-TiO2 compositions and the marking system are shown in Table 1.

Table 1. Alumina-basalt sample codes

Sample code	Alumina (wt. %)	TiO2 (wt. %)
A0	100	-

A5	95	5
A10	90	10
A15	85	15

In order to ensure a homogeneous mixture, each composition was ball-milled in rubber-lined ceramic jars for 2 h using alumina balls and distilled water as the milling media and then sieved to pass through 38 μm. After drying in an oven at 110 °C for 24 hours, the mixtures were granulated in moist conditions and then semidry pressed at 100 MPa to prepare rectangular shaped specimens with the size of 5X8X40 mm.

After shaping process, all samples were dried in an oven at 110 °C for 24 hours and were sintered in an electric furnace with a heating rate of 5 oC/min at 1500, 1550, 1600 and 1650 oC for 2 h. Then, the sintered samples were cooled to room temperature in the furnace. The flow chart of experimental procedure and the macro images of the sintered specimens were given in Fig. 1 and Fig. 2, respectively.

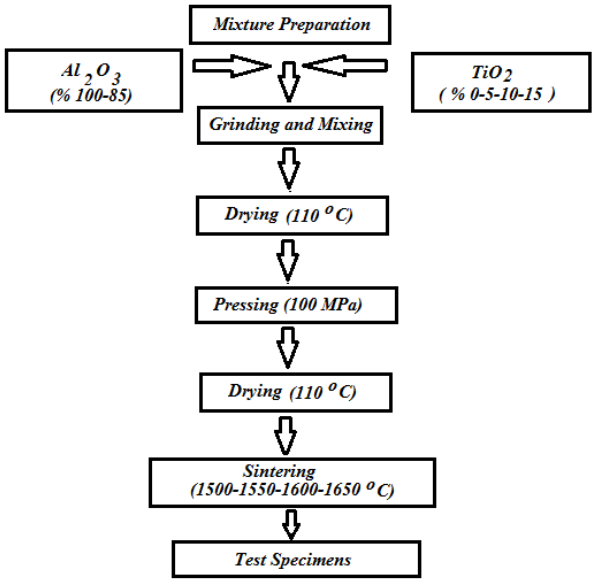


Figure1. The flow chart of the experimental procedure

After sintering, the sintered samples were subjected to physical tests such as firing shrinkage, relative density, flexural strength test by 3-point bending method and hardness. The crystalline phases of the sintered samples were identified by X-ray diffraction analysis (XRD, JEOL MDI/JADE6) with Cu Kα (λ = 1.54056 A˚) radiation. The micro structural characterization of fracture surfaces of sintered samples were examined using a JEOL JSM 6600 scanning electron microscopy (SEM).

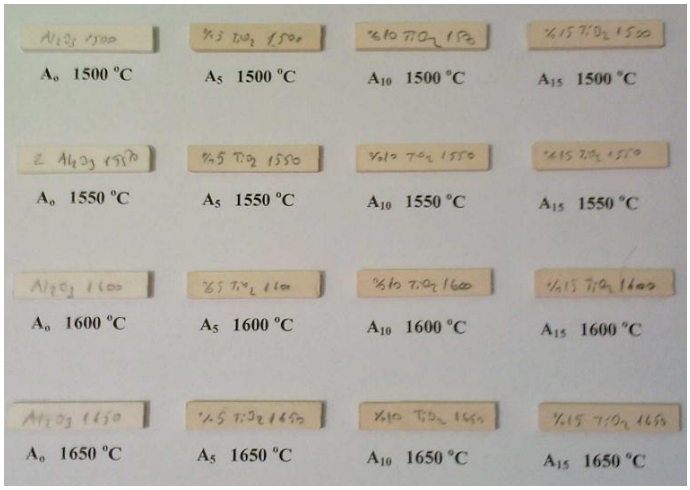


Figure 2. Macro images of test specimens

3. RESULT AND DISCUSSION

The firing shrinkage values of TiO2 reinforced alumina ceramics depend on sintering temperatures and TiO2 addition is shown in Figure 3. The firing shrinkage was increasing in all specimens with increasing sintering temperature due to sintering effect by dimensional reductions. The firing shrinkage of A0 is less than TiO2 doped samples. Al2TiO5 phase is observed in TiO2 reinforced alumina ceramics as given in the literature Soo et al (2003). Al2TiO5 phase was also detected in our studies given below. Al2TiO5 are generally spherical or angular particles. They were along the grain boundary and triple junction points as expressed in literature (Sathiyakumar 2008). This effect can be seen in SEM microstructures given below. It is probably that the firing shrinkage of TiO2 reinforced alumina ceramics was prevented by Al2TiO5 phase.

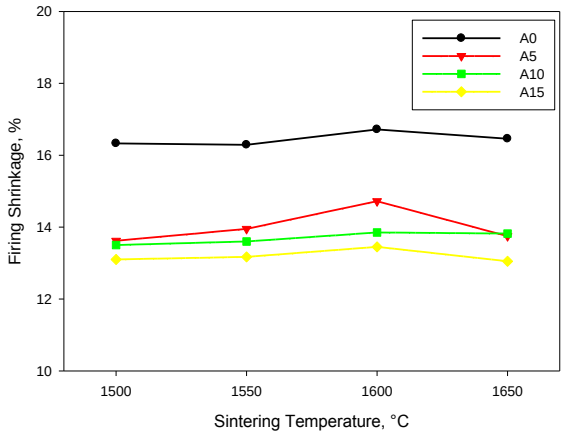


Figure 3. The firing shrinkage test results versus sintering temperature

The relative density values of TiO2 reinforced alumina ceramics depend on sintering temperatures and TiO2 addition is shown in Figure 4. When the sintering temperature increases, the porosities remain into the grains of alumina ceramics as a result of rapid grain growth. This is obstacle for reaching to theoretical density of alumina ceramic and causes decreasing of densities (Barsoum 1997,Kalpakjian 1997). Since the density of Al2TiO5 phase is lower compared to densities of alumina and TiO2, densities increases with increasing TiO2 addition Soo et al.(2003).

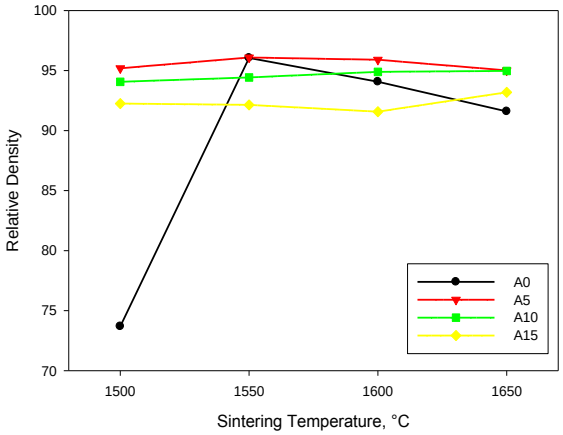


Figure 4. The relative densities depending on sintering temperature

The flexural strength of composites is given in Figure 5. With the increase in sintering temperature, the highest strength value was obtained in the TiO2 free alumina ceramic sintered at 1550 °C. The decreasing of strength was observed via increasing of temperature depending on the grain growth and the pores remaining into grains (Barsoum 1997,Kalpakjian 1997). The flexural strength values of the samples including TiO2 are lower than the samples not including TiO2. Investigation of the effect of TiO2 addition on flexural strength is compressive process in literature, the flexural strength value increases up to the addition of TiO2 2 % and it decreases above TiO2 4 % addition (Sathiyakumar 2002). The flexural strength values of the samples including TiO2 are in agree with the literature values and it is lower compared to the samples not including TiO2.

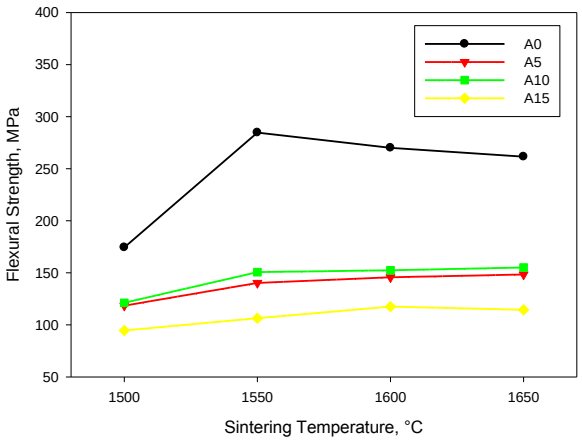


Figure 5. The flexural strength values versus sintering temperature

As seen in Figure 6, high hardness results were observed in high densification conditions. The highest hardness was determined in the 96.05 relative density value of alumina ceramic sintered at 1550 °C. It is correlated with the literature [Yildirim 2002]. The hardness of the samples including TiO2 is not high as much as TiO2 free alumina ceramics. It is reported that Al2TiO5 and TiO2 phases in alumina matrix cause increasing of hardness Soo et al. (2003),Anerisis et al. (2007). Small amount of TiO2 addition has positive role on sintering in alumina composites and the presence of this second phase in matrix provides better mechanical properties. The hardness increases with increasing TiO2 content in alumina matrix composites, it is correlated with the literature Soo et al. (2003).

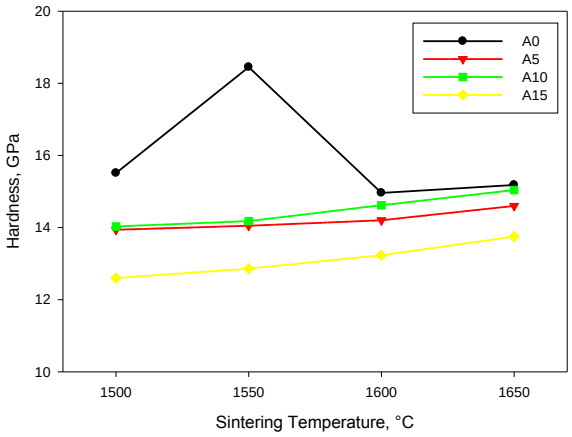
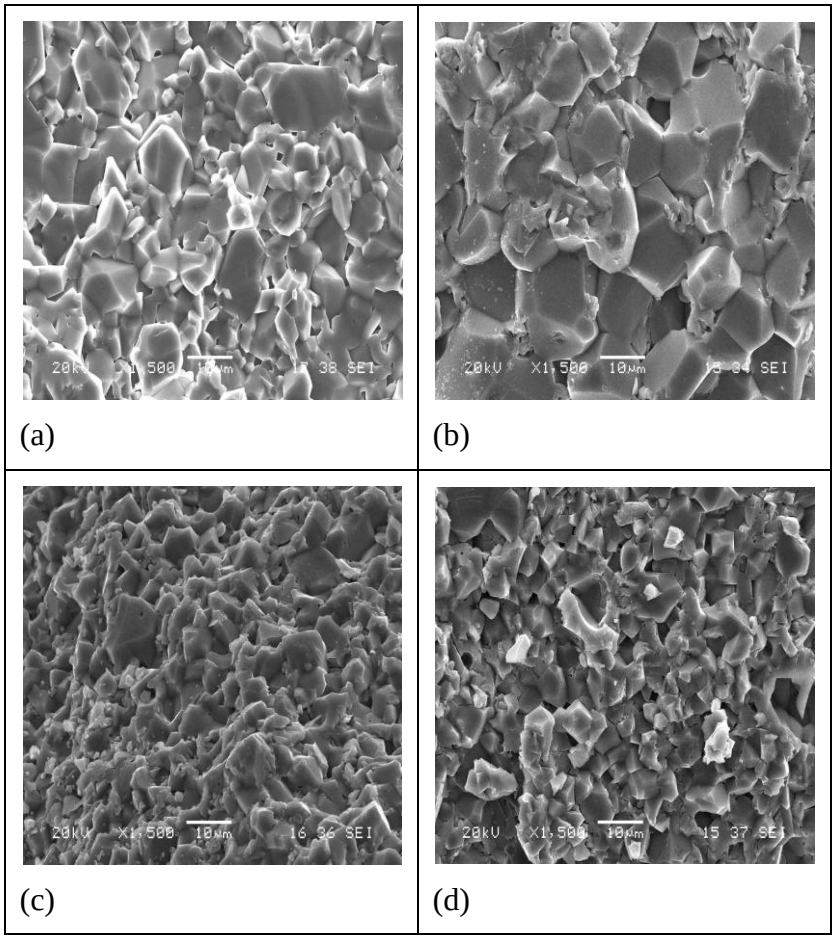


Figure 6. The hardness measurements depending on sintering temperature

XRD analysis results showed that □-Al2O3 phase was determined in the all samples coded A0. In the samples including TiO2, TiO2 (rutile) and Al2TiO5 phases are other phases determined by XRD.

As seen in Figure 7, Al2TiO5 phase formed via the reaction between Al2O3 and TiO2 at 1280 °C was seen as lighter zones in grain boundaries and intersection points of the grains. Abnormal grain growth was not observed in the alumina ceramic including TiO2 compared to

alumina ceramics. Finer grain structure was determined in these samples due to presence of Al2TiO5 phase as obstacle against grain growth.



een as lighter zones in grain boundaries and intersection points of the grains in SEM microstructure. Finer grain structure was determined in composites due to presence of Al_2TiO_5 phase as obstacle against grain growth.

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